

Learner Autonomy of Engineering Students

Validating the PRO-SDLS scale in a Portuguese context

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Abstract—In the European Higher Education Area, lifelong learning has been recognized as an essential element, being critically important given the rapid pace of change of society, namely in engineering and technology. Learner autonomy and self-direction in learning in higher education has become increasingly important as a way to promote lifelong learning and the ability to continuously learn. This study is a first step in the adaptation and validation of a Portuguese version of the Personal Responsibility Orientation to Self-Direction in Learning Scale (PRO-SDLS) to undergraduate engineering students. Using factor and reliability analysis, 12 items of the translated scale showed strong validity and reliability. The findings indicate that the PRO-SDLS can be used with engineering undergraduate students, but there are some differences between the original learner autonomy construct and the one that emerges from this adaptation. More data collection is suggested. The possibility of interviews and focus groups is also mentioned.

Index Terms—engineering students, higher education, learner autonomy, measurement scale, self-direction

I. INTRODUCTION

In the European Higher Education Area, lifelong learning has been recognized as an essential element, being critically important given the rapid pace of change of society [1]. This is particularly true in areas such as engineering and technology where new fields are constantly emerging [2]: what an engineer will need to know several years after graduating will not have been learned in school. So, in engineering, the education that succeeds will be the one that facilitates lifelong learning [3].

In engineering education, EUR-ACE® is a framework and accreditation system of the European Network for Accreditation of Engineering Education (ENAE), which provides a set of standards that identifies high quality engineering degree programmes in Europe and abroad. The EUR-ACE® label is a certificate awarded by an authorised agency to a HEI (Higher Education Institution) in respect of each engineering degree programme which it has accredited, and that fulfil the programme outcome standards as specified in the EUR-ACE® Framework Standards. One of these Framework Standards is transferable skills, which includes an undergraduate being able to recognise the need for, and have the ability to engage in independent lifelong learning.

But lifelong learning means the ability to evaluate one's own learning needs and ways to continuously learn and improve, because "no learner can be effective in more than a very limited area if he or she cannot make decisions for themselves about what they should be learning and how they should be learning it" [4]. That is why Boud [4] argues that is not likely that students who are dependent

on their teachers are going to be as effective in the world of learning or subsequent employment as those who have developed strategies which enable them to find and use their own resources for learning, emphasizing the importance of learner autonomy as a key element in higher education. Also, learner autonomy and self-direction in learning has been found to be related with better academic achievement.

The first definition of learner autonomy is attributed to Holec in 1979 [5] as being "the ability to take charge of one's own learning". Other definitions include "The ability to control one's learning" [6], "Learner's ability and willingness to make choices independently" [7] and "a capacity and willingness to act independently and in cooperation with others" [8].

For Holec [5] learner autonomy is acquired. An individual with this ability may or may not use it. Learners must be willing to do so, but they also need the opportunity to do so. The learner that has this ability and makes full use of it is involved in self-directed learning. According to Holec [5] learner's autonomy is an individual capacity and self-directed learning describes the way in which an autonomous learner is involved in the teaching-learning transaction.

So, learner autonomy depends on an ability, that can be acquired, but also on the willingness to mobilize this ability for learning. According to Littlewood [9], the "ability depends on possessing both knowledge about the alternatives from which choices have to be made and the necessary skills for carrying out whatever choices seem most appropriate. Willingness depends on having both the motivation and the confidence to take responsibility for the choices required".

In spite of the importance of learner autonomy for lifelong learning, and the need to engineers continuously update their knowledge and skills, the majority of the published material and research on learner autonomy is related with university courses from humanities and social sciences, and not with engineering and technology [10] and these qualities are typically less emphasized in engineering education itself [11]. Also, as Chen and Lord [1] point out, given the importance of learner autonomy and lifelong learning, there are surprisingly few instruments to measure it in higher education.

That is why this study aim is the adaptation and validation of the PRO-SDLS scale [12] to Portuguese undergraduate engineering students, which measures self-directedness in learning based on an operationalization of the personal responsibility orientation (PRO) model of self-direction in learning. The procedure and data presented here refers to the pilot study, meaning that additional work will be done.

Instead of trying to develop a new scale for Portuguese undergraduate engineering students, the choice was to use an existing one, because, as Punch points out [13] “the more complex the variable, the more work, time and resources are required to achieve good measurement. This is an argument for using what already exists”. Also, the more an instrument is used, the more is known about its properties. The use of an already existing instrument, also allows comparisons to be made between researches from different countries.

II. INSTRUMENT: PRO-SDLS SCALE

In 2011, Stockdale and Brockett [12] developed a reliable and valid instrument to measure self-directedness in learning among college students based on an operationalization of the personal responsibility orientation (PRO) model of self-direction in learning. They felt that, in spite of the existence of several other scales, none of them were recent and did not address the specificity of higher education students.

The personal responsibility orientation (PRO) model of self-direction in learning is a conceptualization of self-direction by Brockett and Hiemstra [14] that “provides a definitional foundation for understanding and recognizing differences and similarities in self-directed learning as a teaching and learning transaction external to the individual and learner self-direction as a personal orientation internal to the individual. Together they predispose on toward personal empowerment and accepting responsibility for such learning”.

The authors [14] define the self-directed learning component as a “process in which a learner assumes primary responsibility for planning, implementing, and evaluating the learning process”. In this process, the focus is the external factors and characteristics of the teaching-learning transaction, in which teachers play a facilitating role.

That’s why the scale items for this component “will reflect agreement with actions that demonstrate proactively assuming control and initiative for planning, implementing and evaluating the learning process; items that relate to exhibiting control of the learning situation compose one factor, and items that relate to demonstrating initiative compose a second factor” [12].

As for the learner self-direction component, Brockett and Hiemstra [14] define it as “an individual beliefs and attitudes that predispose one toward taking primary responsibility for their learning (...) a learner’s desire or preference for assuming responsibility for learning” and by doing so being motivated to learn. This component also includes learner’s self-efficacy in self-directed activities, as defined by Bandura [15] as “beliefs in one’s capacities to organize and execute the courses of action required to produce given attainments”.

So, the learner self-direction component of the scale “was conceptualized as behaviours relating to learner autonomous motivation and perceived self-efficacy for self-direction in learning” [14], including items that relate to motivation and items that relate to self-efficacy.

The PRO-SDLS scale is based on a five-point Likert type format that was found suitable to “best reflect student’s degree of agreement or disagreement with statements pertaining to self-perceptions of their actions and beliefs in self-directed learning opportunities” [12]. The

scale contains 25 items and those that were considered negative with respect to the construct were reverse scored.

The scale has two major components: teaching-learning transaction (TLT) and the learner characteristic (LC), which includes 12 items and 13 items, respectively. In the TLT component, items 2, 9, 10, 15, 17 and 25 refer to initiative, while items 4, 5, 6, 13, 19 and 23 refer to control. In the LC component, items 3, 8, 11, 14, 16, 18 and 20 refer to motivation and items 1, 7, 12, 21, 22 and 24 refer to self-efficacy.

In the initiative factor, the items are related with the willingness to go further by taking the initiative to learn more, and it includes doing extra work in a course (item 2), preferring to take the initiative to learn new things rather than waiting for the teacher (item 9), finding and using one’s own materials in courses (item 10), learning course related subjects even after its successful completion (item 15), collecting additional information even after the successful completion of courses (item 17) and not relying on the teacher to know what to do to be successful (item 25).

In the control factor, the items are related with a certain degree of independence regarding the teacher in several key aspects of the teaching-learning transaction, such as making changes needed to succeed independently (item 4), taking responsibility for learning (item 5), self motivation for learning (item 6), managing time to complete tasks in classes (item 13), prioritizing learning goals (item 19) and organizing study time (item 23).

In the motivation factor, the items are related with wanting to learn and enjoying it, and comprises aspects like seeing the connection between what is done in courses and personal goals and interests (item 3), wanting to complete learning activities (item 8), doing learning activities with a purpose (item 11), enjoying learning activities or perceiving them as relevant (item 14), doing course activities to learn more and not because of grades (item 16) or guilt (item 18) and finding classes useful and interesting (item 20).

In the self-efficacy factor, the items are related with believing and trusting one’s capacity to do what needs to be done, such as being confident in one’s ability to motivate one’s self (item 1), to prioritise learning goals (item 7), to take personal control of learning (item 12), to take primary responsibility for learning (item 21), to independently find extra materials for courses (item 22) and to independently carry out student plans (item 24).

For the development of the PRO-SDLS scale, convenience sampling was used. A total of 518 undergraduate (educational psychology course) and graduate (adult learning course) college students, voluntarily participated. According to Stockdale and Brockett [12], “the investigation comprised three research studies, the first two of which served as pilots for this main study (...). A confirmatory analysis was performed with the 25 items to determine if the model conformed to the data. Data from the final scale were then used to examine issues of reliability”.

The authors [12] also provided evidence of scale validity, specific criteria validity, congruent validity and convergent validity. “Incremental validity statistics were also used to demonstrate that the PRO-SDLS scale added significant unique variance to the prediction of self-direction above and beyond scores from the traditional scales” [12].

III. METHOD

A. Participants

The participants were undergraduate higher education Portuguese students of two engineering courses (first cycle) of Polytechnic of Porto School of Engineering (ISEP). In the school year 2006/2007, ISEP studies cycles were adapted to the Bologna process, allowing for a segmentation of the programmes offered: the first segment, with a duration of three years, ministers, in depth, the instrumental theoretical knowledge, the scientific basis of technologies and the study of mainstream technologies inherent to the specialties, complemented with the approach of the organization and management of the production system (undergraduate degree); the second segment, with a duration of two years, provides the student a greater freedom to customize his training route to his needs, allowing him to focus on more specialized scientific-technological sectors (master's degree). Both studies cycles are career orientated.

With roots dating back to 1852, ISEP had 5294 undergraduate students (according to the 2011 School's report). Convenience sampling was adopted.

A total of 162 students (154 men and 8 women) agreed to participate in the study. The students age ranged from 18 to 57 years ($M=22.36$, $SD=6.43$). Most were first year students (47.5%); 37.7% were second year students and 14.8% were in the third year. First year students were younger ($M=20.06$, $SD=3.46$) than second year ($M=22.87$, $SD=6.14$) and third year students ($M=28.42$, $SD=9.73$).

Of the 162 students, 97 students (59.9%) attended classes during the day, while 65 (40.1%) did it at night because they worked during the day. Students attending classes during the day were younger ($M=20.27$, $SD=3.62$; range from 18 to 41) than those attending it at night ($M=25.48$, $SD=8.23$; range from 18 to 57).

B. Procedure

The adaptation of PRO-SDLS scale began by contacting its author, who was kind enough to send it by email and gave permission to its use and translation into Portuguese. A first translation was made by the investigator and reviewed by three experts (one in self-direction, another in educational sciences and another one in language learning). In order to check for ambiguous meanings in the scale items, a group of twelve engineering students were asked to answer the translated version. Their suggestions were taken into consideration.

Students were approached during classes (with the teachers' permission and collaboration) in October of 2012 and asked whether they would complete the paper-based questionnaire. Students completing the paper questionnaire were told by the investigator what the purpose of the study was, that the data collection was anonymous, and that returning the completed questionnaire to the researcher was taken as providing informed consent. If they did not want to participate in the study they simply returned a blank questionnaire. Approval for the study was obtained from the President of the School of Engineering.

After data collection, the validity and reliability were tested. Exploratory factor analysis (principal components analysis extraction method; varimax rotation) was used to test the validity of the scale. The indicator of the scale's reliability was internal consistency, and Cronbach's alpha

was performed. Pearson's product-moment correlation was used to confirm the relationship between the factors.

Afterwards, the factors identified through this exploratory factor analysis were assessed through confirmatory factor analysis. By using exploratory factor analysis, the data was analysed without too many constraints, allowing any number of factors to emerge [16], with a structure that could be different from the original scale. With confirmatory analysis, the degree to which the data met the structure found in exploratory analysis was accessed, with two absolute indices (relative Chi Square index, $CMIN/DF$ and goodness of fit index, GFI), two relative indices (comparative fit index, CFI and Tucker-Lewis index, TLI) and one discrepancy index (root mean square error of approximation, $RMSEA$).

CFI/DF index evaluates the quality of the model *per se*, being 1 for a perfect adjustment. Values between 1 and 2 are considered to be good [17].

GFI index measures the fit between the amount of the observed covariance and the model, being 1 for a perfect adjustment. Values between 0.90 and 0.95 are considered to be good [17].

CFI and TLI indices compare a chi-square for the model to one from a model that specifies that all measured variables are uncorrelated. CFI index is 1 for a perfect adjustment. Values between 0.90 and 0.95 are considered to be good [17]. TLI index usually range between 0 and 1. For values near 1 the adjustment is considered very good [17].

The $RMSEA$ estimates the lack of fit in a model compared to a perfect (saturated) model, being less than 0.05 for a very good adjustment and between 0.05 and 0.08 for a good adjustment [17].

IV. RESULTS

The 25 items of the Personal Responsibility Orientation to Self-Direction in Learning Scale were first subjected to exploratory factor analysis (principal components analysis extraction method; varimax rotation) in SPSS 19.0.

In the initial run, seven factors with eigenvalues greater than one were identified. All items loaded substantially in one or more factors, using the criterion of a factor loading less than 0.45 because the sample size was under 200. Two items (item 8 and item 9) loaded almost the same and under 0.50 in two factors and were dropped.

In the next run, one item (item 13) did not load in any factor and was dropped.

In the next two runs, some factors had only two items and so these items were dropped (item 16, item 18, item 12 and item 5).

In the fifth run five factors with eigenvalues greater than one were identified. At this point three items (item 25, item 1 and item 7) were dropped because they loaded in a factor that was different from the one expected, according to the PRO-SDLS theoretical construct. The same happened in the sixth run with item 6. In this run four factors with eigenvalues greater than one were identified.

In the last run two additional items (item 14 and item 2) were dropped in order to increase the variance explained by the factors. The four factors identified accounted for 60.66% of the variance and included 12 items (3, 4, 10, 11, 15, 17, 19, 20, 21, 22, 23, 24), which was three items per factor. Factor one (control; items 4, 19, 23), factor two

TABLE I.
RESULTS OF THE FACTOR ANALYSIS (FACTORS' LOADINGS)

Scale items	Factor loading			
	Factor 1	Factor 2	Factor 3	Factor 4
04	0.896			
19	0.535			
23	0.474			
10		0.582		
15		0.775		
17		0.723		
21			0.530	
22			0.761	
24			0.788	
03				0.737
11				0.589
20				0.771

TABLE II.
RESULTS OF THE FACTOR ANALYSIS (COMMUNALITIES)

Scale items	Communality
04	0.815
19	0.529
23	0.559
10	0.482
15	0.620
17	0.686
21	0.537
22	0.664
24	0.664
03	0.588
11	0.441
20	0.696

(initiative; items 10, 15, 17), factor three (self-efficacy; item 21, 22, 24) and factor four (motivation; item 3, 11, 20) explained 12.53%, 14.50%, 16.28% and 17.35% of the variance, respectively. Factors' loadings are included in table I. Communalities ranged from 0.441 to 0.815 (see table II).

The sample size was adequate with a Kaiser-Meyer-Olkin value of 0.778 and Bartlett's test of sphericity (Quisquare=422.714; df=66) was statistically significant as required. There were 47% of nonredundant residuals with absolute values less than 0.05.

The alpha levels were satisfactory (see table III), being 0.781 for the total scale, 0.574 for factor one (control; items 4, 19, 23), 0.562 for factor two (initiative; items 10, 15, 17), 0.685 for factor three (self-efficacy; item 21, 22, 24) and 0.648 for factor four (motivation; item 3, 11, 20). As for the scale components, the Cronbach's alphas were also satisfactory, with 0.664 for the teaching-learning transaction and 0.745 for the learner characteristic.

TABLE III.
RESULTS OF THE SCALE'S RELIABILITY

Components	Factors	Cronbach's alpha	
Teaching-learning transaction	Control	0.574	0.664
	Initiative	0.562	
Learner characteristic	Self-efficacy	0.685	0.745
	Motivation	0.648	
Total PRO-SDLS		0.781	

TABLE IV.
RESULTS OF THE CORRELATION ANALYSIS

Factors	Control	Initiative	Self-efficacy	Motivation
Control	1	0.391	0.412	0.388
Initiative	0.391	1	0.222	0.246
Self-efficacy	0.412	0.222	1	0.464
Motivation	0.388	0.246	0.464	1
Total PRO-SDLS	0.749	0.629	0.745	0.747

TABLE V.
PRO-SDLS SCALE DESCRIPTIVE STATISTICS

Factors	N	M	Std. Deviation	Std. Error
Control	162	10.06	1.877	0.147
Initiative	162	9.05	1.897	0.149
Self-efficacy	162	10.83	2.111	0.166
Motivation	162	10.51	2.124	0.167
Total PRO-SDLS	162	40.44	5.759	0.452

A Pearson product-moment correlation was computed to examine the associations between the factors (see table IV). All correlations were significant at the 0.01 level (2-tailed). Factors correlations with learner autonomy (PRO-SDLS total) were strong. Factors correlations among themselves were moderate.

Table V includes descriptive statistics such as means, standard deviations and standard errors for PRO-SDLS scale Portuguese version total and factors.

With the factors of the exploratory factor analysis and using Amos SPSS 19.0., the confirmatory factor analysis was performed and factor correlations were obtained (see figure 1 and table VI). Correlations between items and PRO-SDLS scale factors ranged from 0.30 to 0.89. The initiative factor had the highest (0.89) and the lowest (0.30) correlations and self-efficacy factor and its items' correlations were the most cohesive (correlations ranged from 0.62 to 0.67). As for the correlations between the factors, the lowest was initiative and self efficacy (0.28) and the highest was self efficacy and motivation (0.65).

All the indices used to evaluate model fit had acceptable values (see table VII), with GFI, CFI and TLI values greater than 0.90, CMI/DF less than 2 and RMSEA less than 0.08.

V. DISCUSSION AND CONCLUSIONS

The 12-item scale that has been adapted and validated is psychometrically sound, demonstrating the same structure of the original PRO-SDLS by Stockdale and Brockett [12].

The fact that it wasn't possible to validate all 25 items was expected because, as stated by Stockdale and Brockett [12] "an important direction for future research is the need to continue developing instruments designed for specific settings. The conceptualization of the PRO-SDLS could serve as an underlying framework for such instruments; however, the language and focus of each instrument would be aimed at a different target audience", meaning that not all items might be adequate for all cultures and students.

So maybe it is worth examining in more detail what items were included or not in the scale and what consequences this might have for the way in which learner autonomy is defined.

With regard to the teaching-learning transaction component, which includes the control and initiative factors, more autonomous learners will be students who can make themselves the necessary changes to improve learning, who are able to prioritize their learning goals, that effectively organize their study time, which often found and use outside materials for their courses, and who still collect additional information about interesting topics even after the course has ended, continuing to spend time learning about them.

On the other hand, it will not be possible to distinguish more autonomous learners, from less autonomous learners, based on the fact of being responsible for their own learning, motivating easily to learn, completing tasks in class even when the teacher does not impose deadlines, often doing extra work in courses, taking the initiative to learn new things without waiting for the teacher and not depending on the teacher to know what to do in courses to succeed.

In other words, in the context of these engineering students and as the teaching-learning transaction is concerned, it seems to favour learner autonomy, the ability to diagnose learning difficulties, having learning has a goal, organizing study time well, searching and using their own study materials and liking what is being learned.

As for the learner characteristic component, which includes self-efficacy and motivation factors, more autonomous learners will be students who have confidence in their ability to be the primary responsible for their learning, to find support material and to carry out their study plans; also, students that see the relationship between what they do in courses and their interests and goals and complete most of their curricular activities because they want to, considering them useful and interesting.

On the other hand, it will not be possible to distinguish more autonomous learners, from less autonomous learners, based on the belief in one's own ability to consistently self-motivate, to prioritise learning goals and to control one's own learning; also, students not making curricular activities for obligation or guilt, or because of grades, but

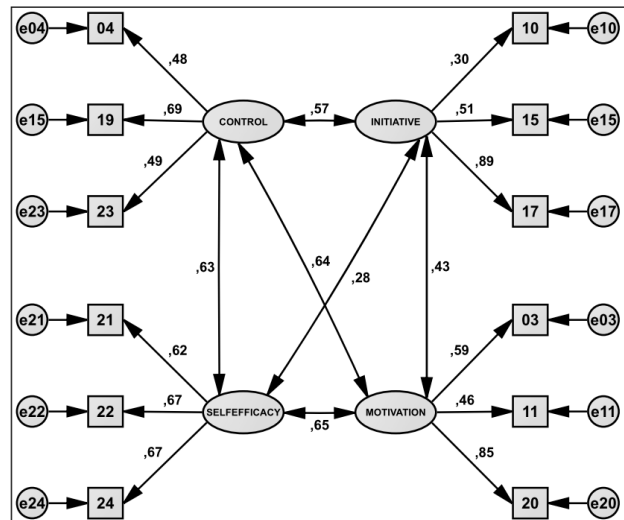


Figure 1. Four factor model (12 items) of the Portuguese version of the PRO-SDLS scale

TABLE VI.
RESULTS OF THE CORRELATION BETWEEN PRO-SDLS FACTORS
(PORTUGUESE VERSION, 12 ITEMS)

Factors	Control	Initiative	Self-efficacy	Motivation
Control	1	0.57	0.63	0.64
Initiative	0.57	1	0.28	0.43
Self-efficacy	0.63	0.28	1	0.65
Motivation	0.64	0.43	0.65	1

TABLE VII.
SUMMARY OF GOODNESS-OF-FIT INDICES FOR THE PRO-SDLS MODEL
(PORTUGUESE VERSION, 12 ITEMS)

Indices	Value	Acceptable values [17]
CMI/DF	1.413]1;2]
GFI	0.933	[0.90;0.95[
CFI	0.946	[0.90;0.95[
TLI	0.926	[0.90;0.95[
RMSEA	0.051	[0.05;0.80[CI 90%

because they like it or it seems relevant for their studies it will not allow to distinguish more and less autonomous learners. Also, it is important to mention that in self-efficacy factor, none of the negative items were included in scale and that did not happen with any of the other factors.

In other words, in the context of these engineering students, and as the learners' characteristics is regarded, it seems to favour learner autonomy, believing that they are the primary responsible for what is learned and that they are able to achieve what is planned and finding the support material needed, and also considering curricular activities useful and relevant, taking interest in performing them.

Considering that the learner autonomy combines these two components, and according to the construct that the Portuguese version of the PRO-SDLS scale (12 items)

enables to identify, this autonomous learner wants to learn, believes that he is able to learn and that this primarily depends on himself; is able to organize effectively his study time and to diagnose his difficulties; believes in his ability to find supporting material and uses frequently support material that he found himself; likes to learn, considers curricular activities useful and relevant and has an interest in performing them.

Emerge as not distinctive aspects in learner autonomy, the role of duty, guilt and grades on learning, which seem to be important for all students. There is also no difference in the fact that students can complete the tasks in classes even when the teacher does not impose time limits and do more than what they are being asked in their courses. This last aspect can refer to recent changes related to the adequacy to the Bologna process and the possibility of maybe not being clear to students that what is being asked of them is not limited to contact hours, but that it depends on the credit units as a measure of the student's workload.

Point out the fact that the Portuguese adaptation of the PRO-SDLS scale includes the item referring to believing one is the primary responsible for learning, but does not include the item referring to one being responsible for learning. The opposite happens to the item relating to being able to prioritise learning goals which is included in this version of the scale, what does not happen with the item referring to believing one is able to prioritise learning objectives. That is, it seems more important to the learner autonomy of these students, on one hand believing that one is responsible for learning, regardless of whether or not one is, and on the other hand, being able to prioritise learning goals, regardless of whether one believes or not in that capability.

As mentioned earlier this is a pilot study, and so, more data will be collected. Misconceptions about learner autonomy will also be investigated with a series of interviews and focus groups, in order to shed light on some of the issues mentioned. The possibility of adding additional items to Portuguese validated scale in order to make it more specific to engineering students will be considered.

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